Requirements Engineering for Sustainability - Sustainability Analysis

Birgit Penzenstadler
birgit.penzenstadler@csulb.edu
www.csulb.edu/~bpenzens

@twinkleflip
#SustainabilityDesign
#KarlskronaManifesto

Timeline

- Tuesday 29.3
  - 10-12 Open lecture "Software engineering for sustainability – The Karlskrona manifesto", Room 4511
  - 12-16 Opening of the course, Room 7441
- Wednesday 30.3
  - 18-22 LUT Beach Sauna, student idea presentations & discussions
- Thursday 31.3
  - 10-12 Stakeholder model and goal modelling, Room 4511
  - 12-14 Course work, Room 4511
- Friday 1.4
  - 10-12 System vision, Sustainability analysis and use cases, Room LS204
  - 12-14Course work, Room LS 204
- Monday 4.4.
  - 10-14 Intermediate presentations, Room 7441
- Tuesday 5.4
  - 12-16 Course work, Room 7441
- Wednesday 6.4
  - 8-10 Briefing for presentations, Room 7441
  - 10-12 Course work, Room 7441
- Thursday 7.4
  - 10-14 Course work, Room 7441
- Friday 8.4
  - 12-16 Final presentations, Room 7441

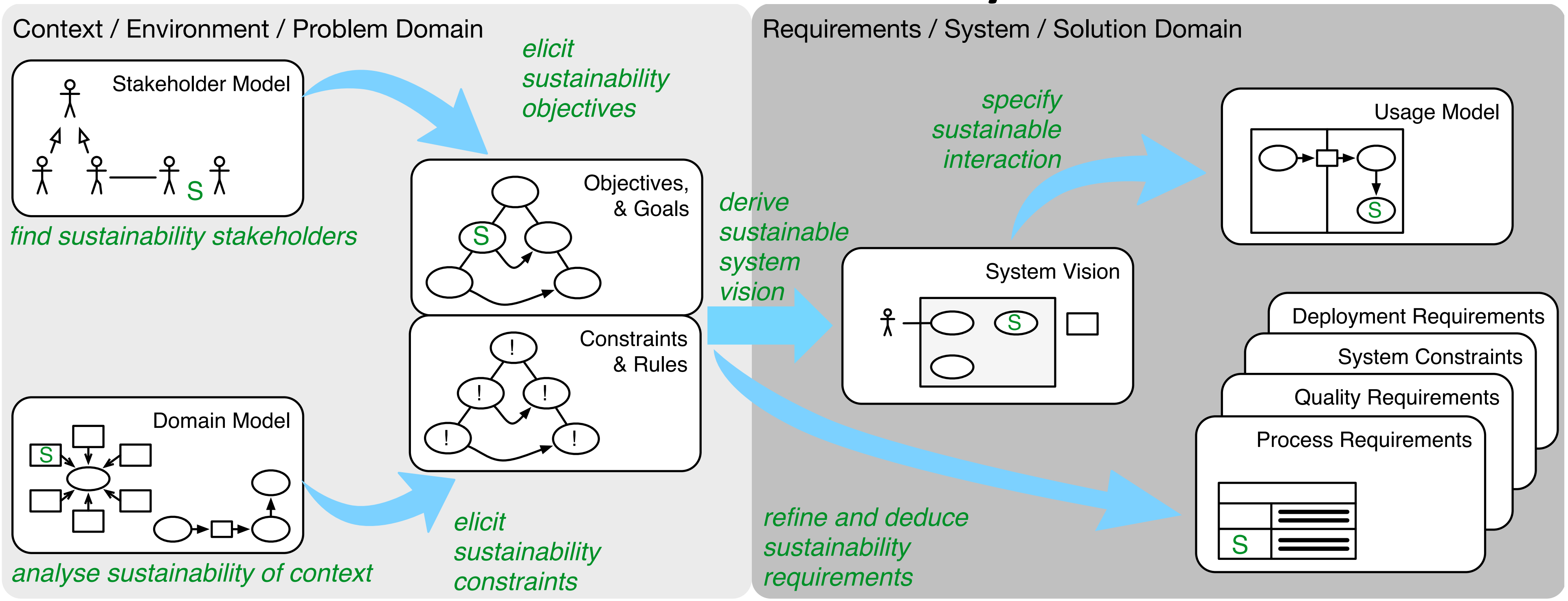
Outline & Overview

1. Sustainability Analysis

→This is your playground

→You get as much out of this course as you put in.

Requirements Engineering for Sustainability



Example checklist for analyzing environmental sustainability for a software system.

Guiding Questions for Green RE:

1. Does the system have an explicit sustainability purpose?
2. Which impact does the system have on the environment?
3. Is there a stakeholder for environmental sustainability?
4. What are the sustainability goals and constraints for the system?

Sustainability Analysis

Sustainability Analysis

- “What does X mean for my/our system?”
- Sustainability dimensions
  - Environmental, individual, social, economic, technical
- Orders of impact
  - Immediate
  - Enabling
  - Structural

Orders of effect

1. *Immediate effects* are the direct effects of the production, use, and disposal of software systems. This includes the immediate benefit of system features and the full life-cycle impacts, such as a life-cycle assessment (LCA) would include. An LCA evaluates the environmental impact of a product's life from the extraction of raw materials to its disposal or recycling.
2. *Enabling effects* arise from a system's application over time. This includes not only opportunities to consume more (or fewer) resources but also other changes induced by system use.
3. *Structural effects* represent "persistent changes observable at the macro level. Structures emerge from the entirety of actions at the micro level and, in turn, influence these actions." Ongoing use of a new software system can lead to shifts in capital accumulation; drive changes in social norms, policies, and laws; and alter our relationship with the natural world.

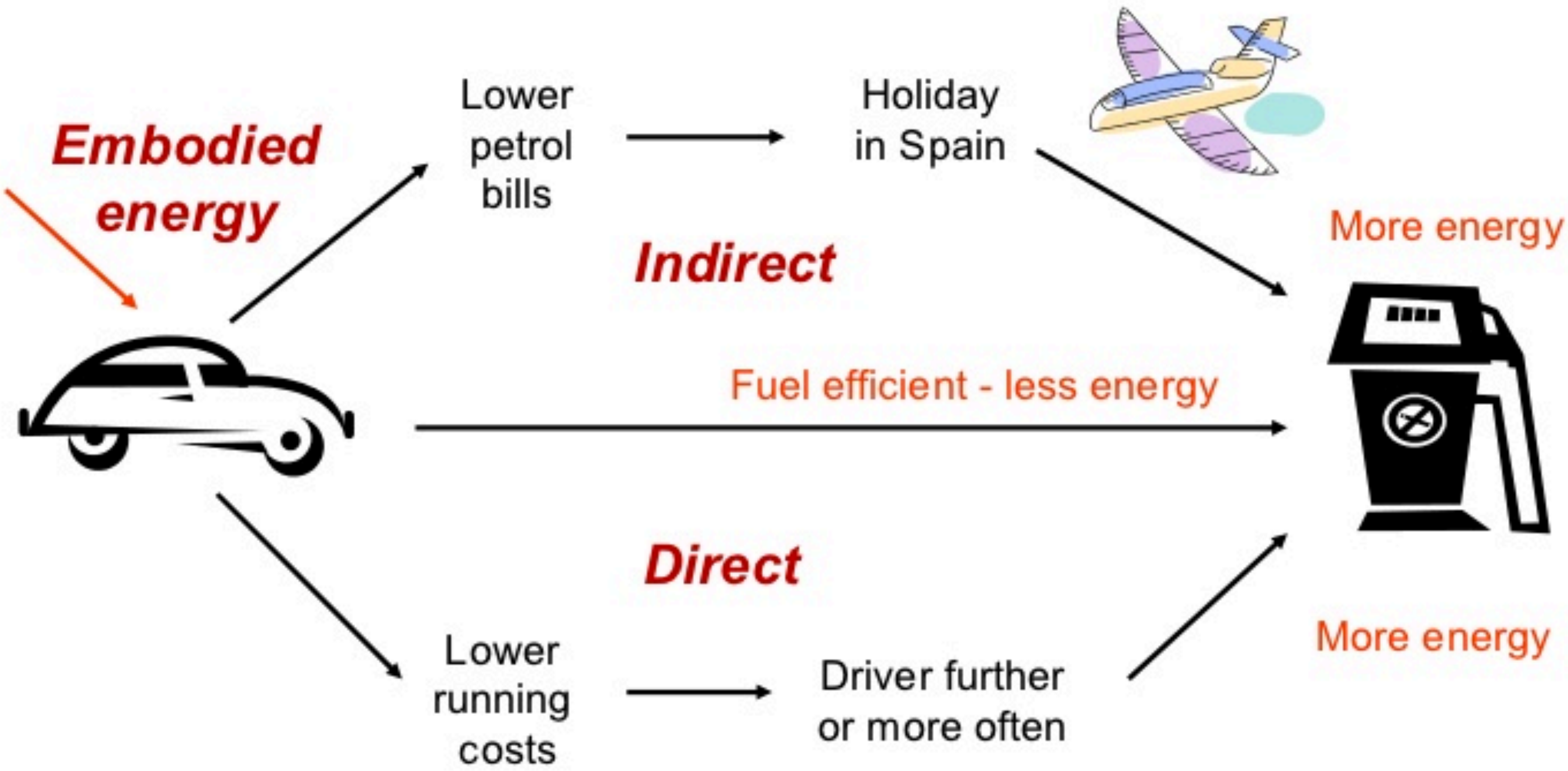
Rebound effect

- In conservation and energy economics, the rebound effect (or take-back effect, RE) is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioral or other systemic responses. These responses usually tend to offset the beneficial effects of the new technology or other measures taken. While the literature on the rebound effect generally focuses on the effect of technological improvements on energy consumption, the theory can also be applied to the use of any natural resource or other input, such as labor. The rebound effect is generally expressed as a ratio of the lost benefit compared to the expected environmental benefit when holding consumption constant.
- For instance, if a 5% improvement in vehicle fuel efficiency results in only a 2% drop in fuel use, there is a 60% rebound effect (since (5-2)⁄5 = 60%). The 'missing' 3% might have been consumed by driving faster or further than before.
- The existence of the rebound effect is uncontroversial. However, debate continues as to the magnitude and impact of the effect in real world situations. Depending on the magnitude of the rebound effect, there are five different rebound effect types:

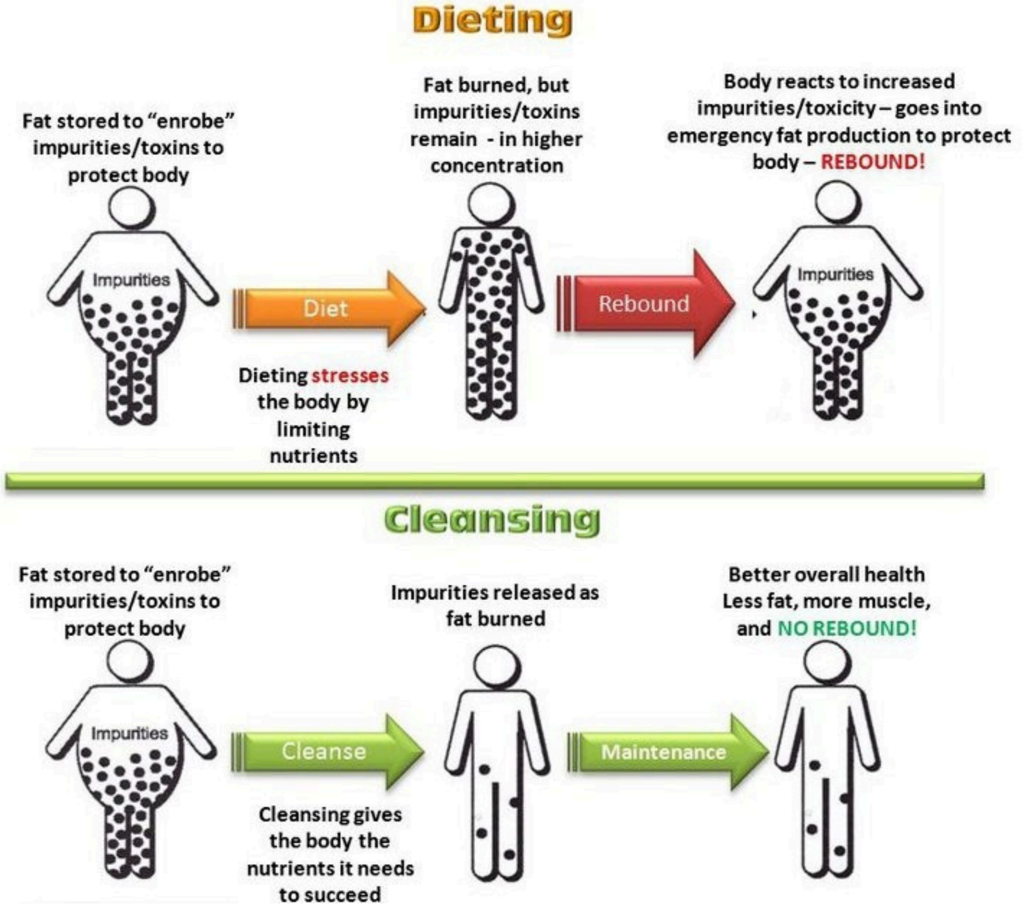
1. Super conservation (RE < 0): the actual resource savings are higher than expected savings – the rebound effect is negative. This occurs if the increase in efficiency reduces costs.
2. Zero rebound (RE = 0): The actual resource savings are equal to expected savings – the rebound effect is zero.
3. Partial rebound (0 < RE < 1): The actual resource savings are less than expected savings – the rebound effect is between 0% and 100%. This is sometimes known as 'take-back', and is the most common result of empirical studies on individual markets.
4. Full rebound (RE = 1): The actual resource savings are equal to the increase in usage – the rebound effect is at 100%.
5. Backfire (RE > 1): The actual resource savings are negative because usage increased beyond potential savings – the rebound effect is higher than 100%. This situation is commonly known as the Jevons paradox.

https://en.wikipedia.org/wiki/Rebound_effect_(conservation)
http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-14-39.pdf
http://www.eoearth.org/view/article/155666/

Illustration of rebound effects

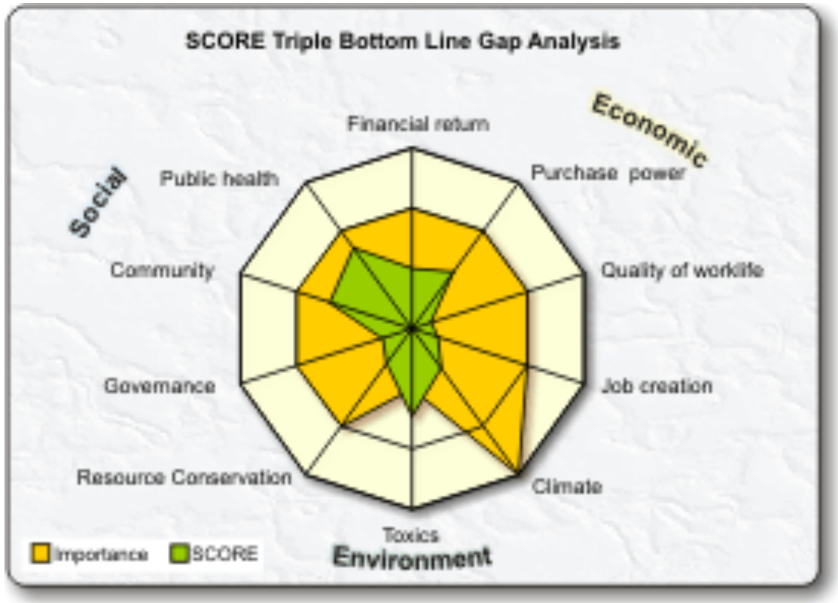


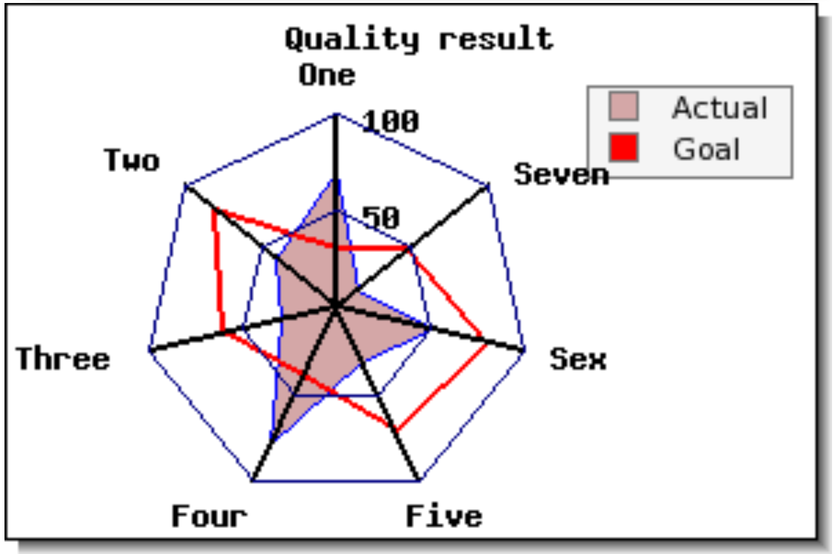
Rebound effect

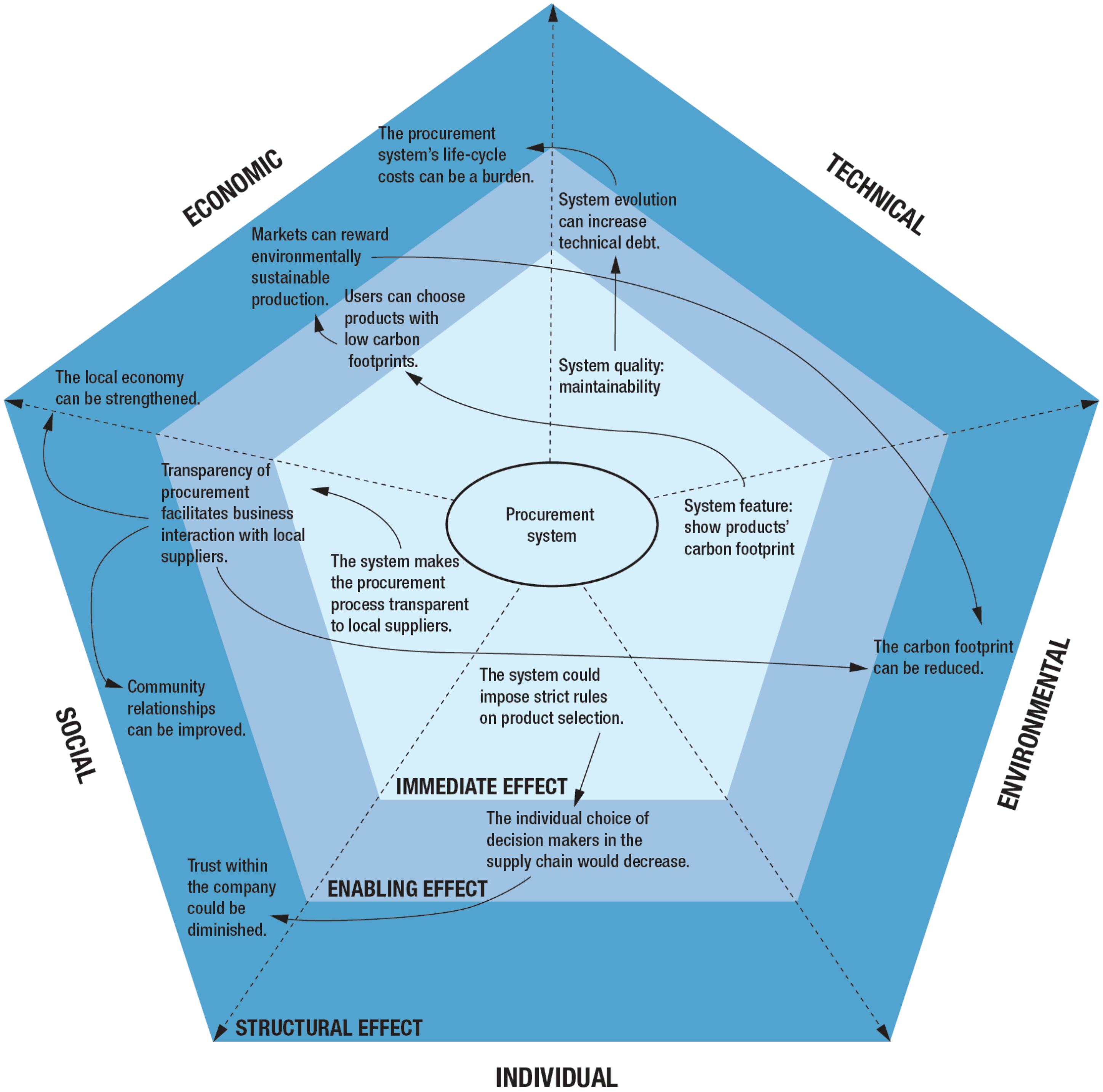


Representation as radar diagram

- Radar chart: Useful when you want to look at several different factors all related to one item.
- Multiple axes along which you can visualize data
- Point near center indicates a low value
- Point near edge indicates a high value
- Coverage allows for (conditional) comparison



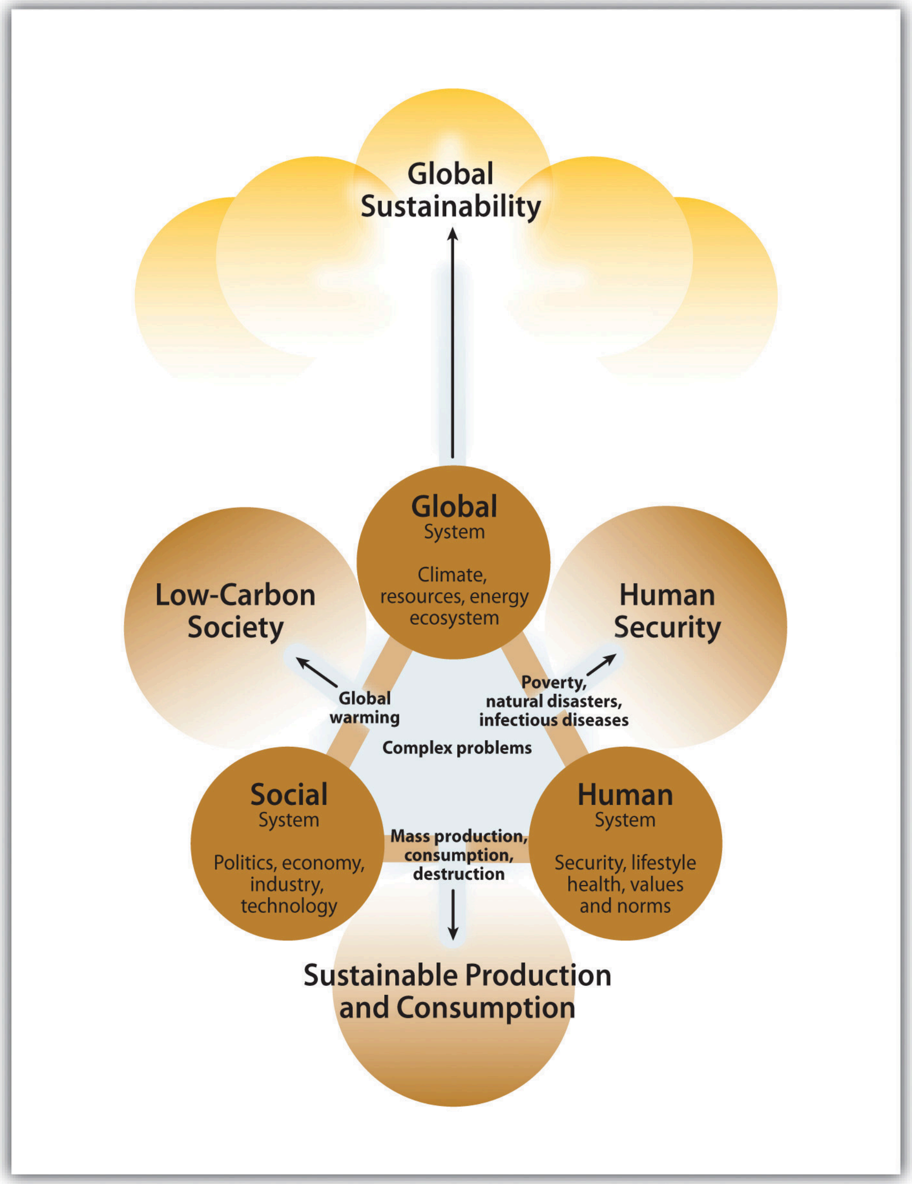


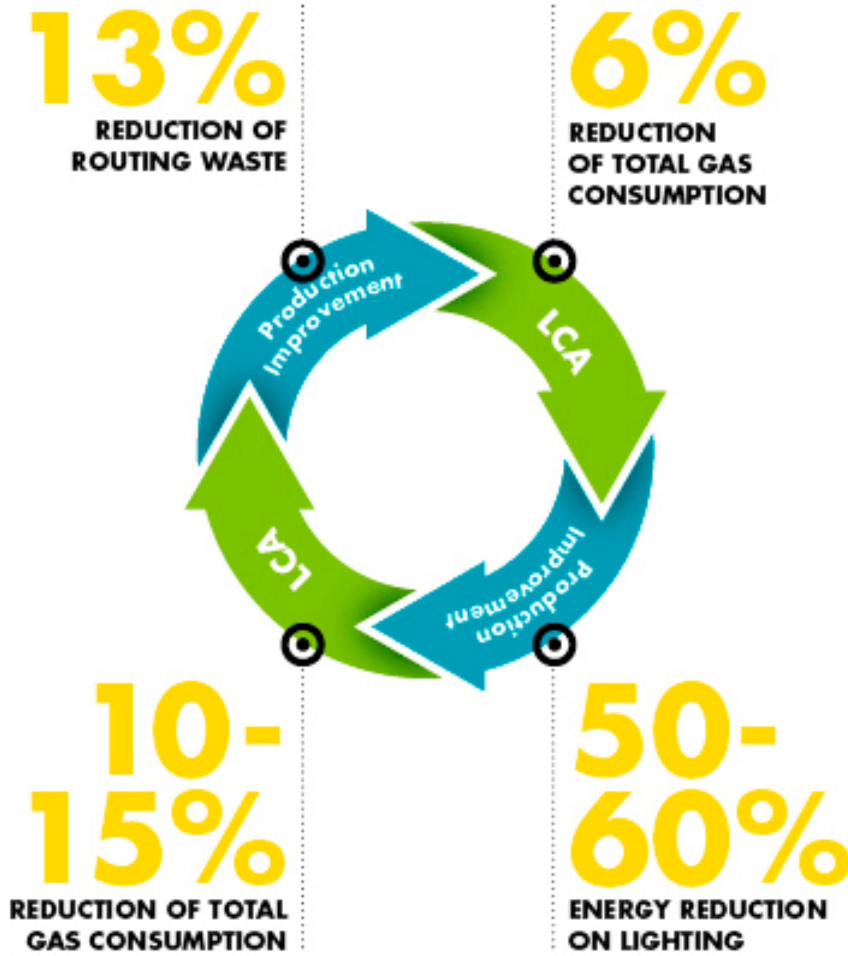

ECONOMIC
TECHNICAL
ENVIRONMENTAL
INDIVIDUAL
SOCIAL
The procurement system's life-cycle costs can be a burden.
System evolution can increase technical debt.
Markets can reward environmentally sustainable production.
Users can choose products with low carbon footprints.
System quality: maintainability
The local economy can be strengthened.
Transparency of procurement facilitates business interaction with local suppliers.
Procurement system
System feature: show products' carbon footprint
The system makes the procurement process transparent to local suppliers.
The carbon footprint can be reduced.
The system could impose strict rules on product selection.
Community relationships can be improved.
IMMEDIATE EFFECT
The individual choice of decision makers in the supply chain would decrease.
Trust within the company could be diminished.
ENABLING EFFECT
STRUCTURAL EFFECT

Taking the analysis further

1. Visualize results in infographics
2. Estimate impacts using Fermi approximations
3. Deeper analysis using causal loop diagrams (Systems thinking)

1. Further visualization: infographics





2. Fermi Approximations

- In physics or engineering education, a Fermi problem, Fermi quiz, Fermi question, Fermi estimate, or order estimation is an estimation problem designed to teach dimensional analysis, approximation, and such a problem is usually a back-of-the-envelope calculation.
- The estimation technique is named after physicist Enrico Fermi as he was known for his ability to make good approximate calculations with little or no actual data. Fermi problems typically involve making justified guesses about quantities and their variance or lower and upper bounds.
- Historical background: Enrico Fermi's estimate of the strength of the atomic bomb that detonated at the Trinity test, based on the distance traveled by pieces of paper he dropped from his hand during the blast. Fermi's estimate of 10 kilotons of TNT was remarkably close to the now-accepted value of around 20 kilotons.
- Why it works: Approximation method that relies on breaking down a task in calculation steps that include assumptions – errors in assumptions tend to cancel each other out, so the end result is still quite close

2. Fermi Approximations: Example

The classic Fermi problem, generally attributed to Fermi, is "How many piano tuners are there in Chicago?" A typical solution to this problem involves multiplying a series of estimates that yield the correct answer if the estimates are correct. For example, we might make the following assumptions:

- There are approximately 9,000,000 people living in Chicago.
- On average, there are two persons in each household in Chicago.
- Roughly one household in twenty has a piano that is tuned regularly.
- Pianos that are tuned regularly are tuned on average about once per year.
- It takes a piano tuner about two hours to tune a piano, including travel time.
- Each piano tuner works eight hours in a day, five days in a week, and 50 weeks in a year.

From these assumptions, we can compute that the number of piano tunings in a single year in Chicago is

- (9,000,000 persons in Chicago) ÷ (2 persons/household) × (1 piano/20 households) × (1 piano tuning per piano per year) = 225,000 piano tunings per year in Chicago.

We can similarly calculate that the average piano tuner performs

- (50 weeks/year) × (5 days/week) × (8 hours/day) ÷ (2 hours to tune a piano) = 1000 piano tunings per year per piano tuner.

Dividing gives

- (225,000 piano tunings per year in Chicago) ÷ (1000 piano tunings per year per piano tuner) = 225 piano tuners in Chicago.

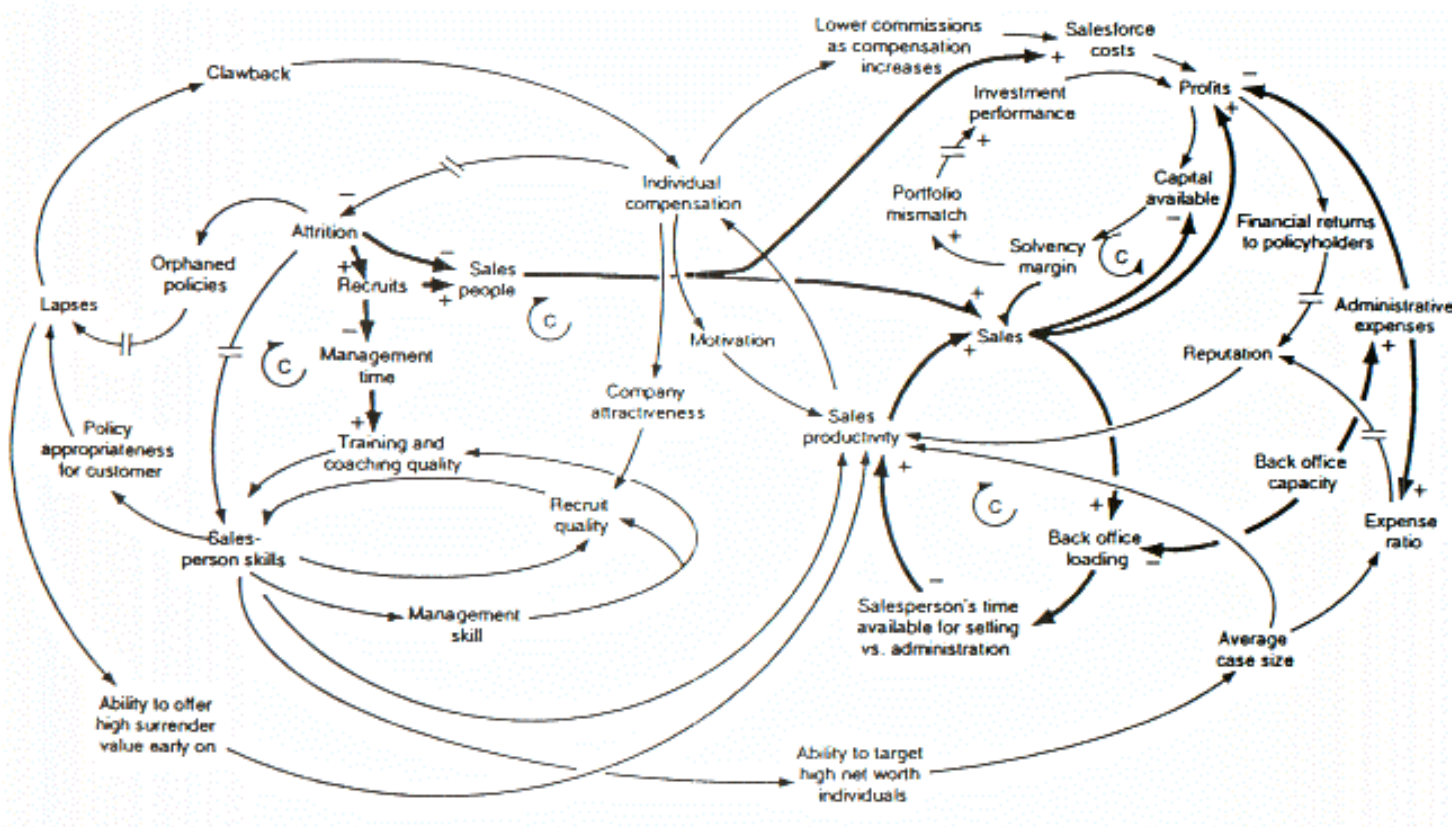
The actual number of piano tuners in Chicago is about 290.

https://en.wikipedia.org/wiki/Fermi_problem
http://lesswrong.com/lw/h5e/fermi_estimates/

3. Causal loop diagrams

- A causal loop diagram (CLD) is a causal diagram that aids in visualizing how different variables in a system are interrelated. The diagram consists of a set of nodes and edges. Nodes represent the variables and edges are the links that represent a connection or a relation between the two variables. A link marked positive indicates a positive relation and a link marked negative indicates a negative relation. A positive causal link means the two nodes change in the same direction, i.e. if the node in which the link starts decreases, the other node also decreases. Similarly, if the node in which the link starts increases, the other node increases as well. A negative causal link means the two nodes change in opposite directions, i.e. if the node in which the link starts increases, the other node decreases and vice versa.
- Closed cycles in the diagram are very important features of the CLDs. A closed cycle is either defined as a reinforcing or balancing loop. A reinforcing loop is a cycle in which the effect of a variation in any variable propagates through the loop and returns to the variable reinforcing the initial deviation i.e. if a variable increases in a reinforcing loop the effect through the cycle will return an increase to the same variable and vice versa. A balancing loop is the cycle in which the effect of a variation in any variable propagates through the loop and returns to the variable a deviation opposite to the initial one i.e. if a variable increases in a balancing loop the effect through the cycle will return a decrease to the same variable and vice versa.
- If a variable varies in a reinforcing loop the effect of the change reinforces the initial variation. The effect of the variation will then create another reinforcing effect. Without breaking the loop the system will be caught in a vicious cycle of circular chain reactions. For this reason, closed loops are critical features in the CLDs.
- https://en.wikipedia.org/wiki/Causal_loop_diagram
- Tutorial: http://www.cs.toronto.edu/~sme/SystemsThinking/GuidelinesforDrawingCausalLoopDiagrams.pdf

3. Causal loop diagram - Example



https://upload.wikimedia.org/wikipedia/commons/f/f6/Causal_Loop_Diagram_of_a_Model.png

Todos

Sustainability Analysis

Submit to me as one PDF file per team by the end of today.

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